§25. Simulation of a Hydrogen Beam Emission in a Toroidal Plasma

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Because the measurement of the pitch angle of the internal magnetic field is important to derive the local safety factor, q(r), in toroidal plasma, spectrum of a beam emission in JIPP T-IIU has been simulated for the understanding of the pitch angle diagnostics using the motional Stark effect.[1)]

As is known, the Balmer α line of a beam emission in the plasma is split due to an induced Lorentz electric field $\mathbf{E}=\mathbf{v}_b\mathbf{x}\mathbf{B}$. The polarization direction of the σ component ($\Delta m = \pm 1$) is parallel to vector $\mathbf{U}=\mathbf{L}\mathbf{x}\mathbf{E}$ and that of the linearly polarized π component ($\Delta m=0$) is the direction obtained by rotating the $\mathbf{U}$ around the viewing line by 90^o. Here, $\mathbf{L}$ is the viewing direction. The intensity of the beam emission can be expressed as

$$I(\lambda) \sim \sum_{i,j} g(i) \int\int_{\Omega,V} f \cos^2(\Phi - \alpha) e^{-\theta^2/\theta_o^2} d\Omega dV\,, \quad (1)$$

where, θ_0 is the divergence angle of the j-th Gaussian beamlet of the beam ion source. Φ and α are tilted angle of a polarizer and polarization angle of the beam emission, respectively. g(i) is the weight of the i-th component transition, V is the volume of the viewed region of the beam and Ω is the solid angle of an object lens. The 'f' is the emission rate determined by the beam attenuation and excitation in the plasma. The integration is over the region of (V, Ω, i, j), where the coordinate is satisfied by a relation that

$$\lambda = \lambda_0 (1 + (v_b/c)\cos\beta)(1 + a(i)\lambda_0 |v_b x B|). \quad (2)$$

Here, β is the angle between the beam and line of sight, 'a(i)' is the i-th proportional coefficient for the wavelength splitting of the Stark spectrum. λ_0 is the wavelength of H_α (6562.8 Å) and c is the light velocity. In practical calculation, the simulated spectrum of the beam emission is a convolution of the beam emission and instrumental function of a spectrometer.

The simulation is carried out with the magnetic field of 3 T and the plasma current of 250 kA. The major radius of the tokamak R0=93 cm and the minor radius r=23 cm. The plasma density and temperature at the plasma center are 5.0×10^{13} cm^{-3} and 1.0 keV, respectively and the radial profile is parabola. The beam energy is 40 keV. The beam injection port and the viewing port is separated by 54^o. Fig. 1 shows the simulated spectra of the beam emission at R=1.03 m through 0^o, 45^o, 90^o and 135^o tilted with respect to the horizontal direction. The simulation is also taken into account of the contribution of the Zeemen effect. It is recognized that the motional Stark effect places the most important role when the beam energy is larger than 10 keV.

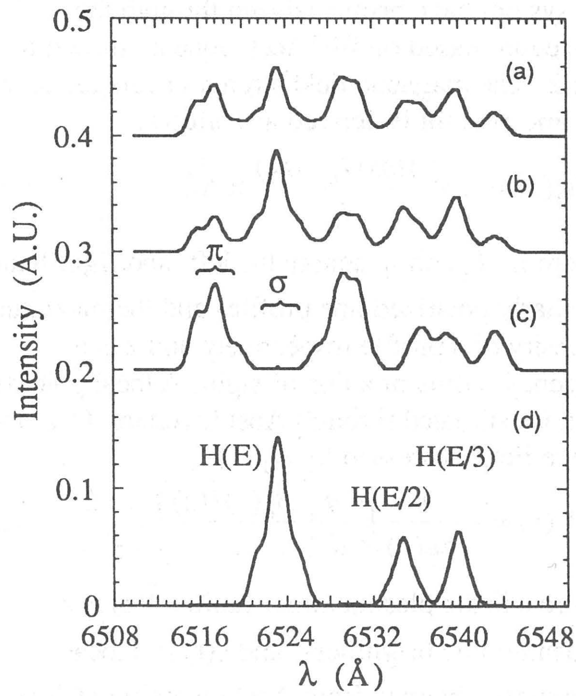

Fig.1 The simulated motional Stark spectra of the beam emission at R=103 cm in the plasma of JIPP T-IIU through the four kinds of the tilted polarizer. a), b), c) and d) are the spectra corresponding to the 135^o, 45^o, 90^o and 0^o tilted polarizer with respect to the horizontal direction.

1) W Mandl et al, Plasma Phys. Control. Fusion **35** (1993)1373-1394.